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DSTO

Measuring the Quality of Mission-Oriented Research

Chun Hui Wang

DSTO-GD-0276

research. Furthermore, the RAE provides benchmarks which are used by institutions in developing and managing their research strategies. Across the UK as a whole, research quality as measured by the RAE has improved dramatically over the last decade

Table 2: The QPIE quality assessment framework

Quality	The intrinsic excellence of the research in world terms
People	The extent to which the output of trained staff meets the requirements of employers.
Impact	The potential for the research output to have a wider impact on other research.
Explotability	The potential for the research to contribute to wealth creation and quality of life through new or improved products, processes and services.

In Australia, the Australian Research Council (ARC) conducted a survey of researchers to establish what researchers in each discipline regarded as appropriate and inappropriate indicators for their field [1]. The survey found very widespread agreement that publication of research results in refereed journals is the most relevant indicators of research performance. The first seven most important indicators are listed in Table 3. Clearly these indicators are best suited to publication-oriented research outputs. Also, there are no indicators on research outcome.

Table 3: Indicators of research quality in academic research [1]

1	Publications in refereed journals
2	Peer reviewed books
3	Keynote addresses (at conferences)
4	Conference proceedings refereed papers
5	Citation impact (publications weighted by journal citation impact
6	Chapters in peer reviewed books
7	Competitive, peer reviewed grants

Among the Federal agencies in the United States, the National Science Foundation (NSF) has a unique mission: to strengthen the overall health of U.S. science and engineering across a broad and expanding frontier. NSF invests in the best ideas from the most capable people, determined by competitive merit review. The merit review system [12,13] is at the very heart of NSF's selection of the projects through which its mission is achieved. NSF evaluates proposals for research and education projects using two criteria: the intellectual merit of the proposed activity and the broader impacts of the proposed activity on society. In particular, NSF uses a PIT framework: People, Ideas and Tools:

> PEOPLE to develop a diverse, internationally competitive and globally-engaged workforce of scientists, engineers and well-prepared citizens. This goal supports the parts of NSF's mission that are directed at (1) programs to strengthen scientific and

> engineering research potential; and (2) science and engineering education programs at all levels and in all fields of science and engineering.
>
> IDEAS to provide a deep and broad fundamental science and engineering knowledge base. This goal supports the parts of NSF's mission directed at basic scientific research and research fundamental to the engineering process.
>
> TOOLS to provide widely accessible, state-of-the-art science and engineering infrastructure. This goal supports the parts of NSF's mission directed at (1) programs to strengthen scientific and engineering research potential; and (2) an information base on science and engineering appropriate for development of national and international policy.

Therefore it is clear that **peer review** is at the heart of virtually all research grant funding bodies, although there are some differences in how this peer review is conducted. For instance, NSF's merit review process involves both mailing and interview, similar to UK's approach, while the ARC employs only the mailing method, hence the criteria used are less comprehensive as compared to that employed in the USA and the UK.

It is also apparent that all the funding bodies employ multiple criteria to assess the quality of research, confirming that the greater the variety of measures used to evaluate research quality, the greater is the likelihood of converging to an accurate measure of research quality. Furthermore, it is interesting to note that individual excellence, and increasingly, team-based excellence, have featured prominently as a quality measure.

3.2 Industrial research

The objectives of industrial R&D organisations are distinctly different from those of universities. The quality of the research undertaken by industrial R&D organisations is ultimately judged via the company's performance in terms of market share, profits, sales and consumer satisfaction. All these are essentially irrelevant for universities. A retrospective approach is required to objectively measure the contribution of research to company sales or profit. For instance, Unilever's annual saving in notional costs of exclusive licences and options was estimated to be approximately equal to the total cost of Unilever research [6], before the value of other outputs from research are counted.

Table 4 summarises some of the main indicators [6] being used in practice.

Table 4: Qualitative measures of quality in industrial R&D

Quality Indicators	Examples
Professionalism	Peer review & feedback; delivery on time and budget
Technology transfer	Successful exploitation
People	Skills and competence; mean age and turnover
Science	Peer review; benchmarking; latest facilitates
Innovations	Number of patents and usage
Business relevance	Strategic focus; synergy and spin-off
Technology insurance	Efficacy of responses; number of incidences/surprises
Knowledge management	Use of computer technology to enhance efficiency

However, most of the measures are historical, subjective and qualitative. As compared to university research, the methodology for measuring the research quality of industrial R&D organisations is far less well developed and explored, a situation not too dissimilar to that existing in mission-oriented organisations as discussed in the next section.

3.3 Mission-oriented research

Nearly all mission-oriented organisations, such as NASA and most of the labs funded by the Department of Defence, Department of Energy in the USA, and CSIRO and DSTO in Australia, do not have formal quality assessment schemes. This is to a large extent due to the lack of requirement so far, as compared to other research funding bodies, to integrate the allocation of R&D resources with performance assessment mechanisms. It is anticipated that, however, the pressure will intensify considerably for mission-oriented organizations to introduce quality assurance, as many governments have now legislated and mandated the integration of performance assessment mechanisms into the research process to help measure the effectiveness of government funded research programmes [14].

For instance, DSTO has introduced a quality review system for its enabling research programme, which accounts for about 10% of the total research portfolio. Quality reviews are conducted for every enabling R&D task through its three-year life span. Normally the reviewing panel consists of three persons: two external experts and one internal expert. Often the diverse range of the type of research makes it difficult to arrive at an absolute measure of quality across the disciplines. But it has been noted by one report [15] from a recent review that the research quality can be assessed to some degree by a number of *peer review* mechanisms, which can be applied both to the track record of the principal investigators and to the project itself. A number of quality indicators have been suggested, as listed in Table 5.

Table 5: Quality indicators for strategic research in DSTO

1	Refereed journal and conference publications.
2	Adoption of research outcomes by clients.
3	National and international enquires for help in problem solving.
4	Requests from other researchers to undertake sabbatical or secondment working with the researchers.
5	Requests to license intellectual property arising from a research project.
6	Benchmarking with competing research groups on an international basis.
7	Other evidence of peer esteem for the work being done.

4. A Proposed Quality Assessment System for Mission-Oriented Research

4.1 Common quality measures

Impact/Outcome

The impact or outcome of research is arguably the most important indication of research quality, especially for applied research or experimental development. In the case of mission-oriented R&D organisations, this means adoption of research outcomes by customers who sponsor the research. This is certainly the most important indicator for industrial R&D organisations. Other quality indicators include spin-off and patents, which are generally most relevant only to industrial R&D organisations.

By its nature, strategic research as conducted by universities and mission-oriented organisations has a long lead-time to yield a useful outcome, and hence is unlikely to result in an immediate outcome within the duration of the project. Therefore the impact of strategic research cannot be measured instantly and a retrospective approach is required. In this case, the track record of the researchers is the most appropriate retrospective quality indicators: past success is the best predictor of future performance.

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ABSTRACT

This report explores suitable measures to assess the quality of mission-oriented research, with the view of identifying appropriate strategies to improve research performance. A peer-reviewed-objective-dependent (PROD) evaluation system is proposed to cater for the broad spectrum of research undertaken by mission-oriented research organisations, ranging from strategic research through to application and development. In the proposed PROD system, quality indicators and the pertinent weightings are adjusted to be consistent with the research objectives. It is possible to obtain a single number to quantify research quality using the bibliometrics method, in which the ratings are determined through peer reviewing. This quality assessment system could provide a useful tool for planning, priority setting, and quality assurance in research and development.

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Measuring the Quality of Mission-Oriented Research

Executive Summary

This report is based on an essay written during the course of Graduate Certificate in Scientific Leadership, Melbourne University, Australia.

The quality of research is vital to any research and development (R&D) organisation, including academic, industrial, and government-funded mission-oriented organisations. With the increasing pressures on public funding for research and from within the research enterprise itself, it is becoming increasingly important to ensure quality control, to demonstrate efficiency in the use of resources, and to provide accountability. The key issue that needs to be addressed can be separated into two major questions: (a) how should the quality of research be defined, and (b) how should this be measured. This issue is critical to planning and priority setting in scientific and engineering research, and decision making in allocation of research funding.

This report explores suitable measures to assess the quality of mission-oriented research, with the view of identifying appropriate strategies to improve research performance. A peer-reviewed-objective-dependent (PROD) evaluation system is proposed to cater for the broad spectrum of research undertaken by mission-oriented research organisations, ranging from strategic research through to application and development. In the proposed PROD system, quality indicators and the pertinent weightings are adjusted to be consistent with the research objectives. It is possible to obtain a single number to quantify research quality using the bibliometrics method, in which the ratings are determined through peer reviewing.

This quality assessment system could provide a useful tool for planning, priority setting, and quality assurance in research and development.

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After obtaining his Ph.D from the University of Sheffield, UK, in 1990, Dr. Chun Wang worked as a research fellow at the University of Sheffield (1990-93) and Sydney University (1993-1994) on fatigue, reliability assessment and biomimatics. Between 1994 and 1995 he worked as a Lecturer at Deakin University and undertook research in mechatronics and advanced composite materials. Since joining DSTO in 1995 he has been working mainly in the areas of fatigue crack growth modelling, fatigue life prediction, computational mechanics, and composite repairs. Dr. Wang is currently a Principal Research Scientist and the Functional Head of Damage Mechancis in the Airframes and Engines Division.

Contents

1. Introduction

The quality of research is vital to any research and development (R&D) organisation, including academic, industrial, and government-funded mission-oriented organisations. With the increasing pressures on public funding for research and from within the research enterprise itself, it is becoming increasingly important to ensure quality control, to demonstrate efficiency in the use of resources, and to provide accountability. The key issue that needs to be addressed can be separated into two major questions: (a) how should the quality of research be defined, and (b) how should this be measured. This issue is critical to planning and priority setting in scientific and engineering research, and decision making in allocation of research funding. Consequently extensive studies have been carried out to identify suitable indicators or criteria for assessing the quality of research, particularly by government funding agencies for university research [1-5].

Virtually all the major research funding bodies worldwide now use composite indicators to asses various aspects of quality: (i) research proposal, (ii) track record of researchers, (iii) intrinsic merit of the research and (iv) relevance of the research. This has been brought about by government and the public trying to define more precisely the purposes for which they invest in scientific research and to assess the results of that investment. It is often argued that investing in second-hand, second quality, research is a waste of money. Therefore both the selection and continuation of research programmes must be made on the basis of outstanding science and potential contribution to the organisation's mission. This requires the establishment of performance indicators to be used in measuring the research quality, goal relevance, service levels, and outcomes of each program activity.

Parallel pressure also exists for industrial research organisations to link research programmes more closely with strategic corporate goals and to increase research performance and productivity, due to the increasing world competition and the trends toward downsizing. Most companies that invest in R&D have shown intense interest in measuring research performance and effectiveness [6]. Therefore, it has become a norm that value-for-money has to be demonstrated both in terms of efficiency and of impact, which can be regarded as indicators of quality.

Excellence is often explicitly stated in the corporate goals of mission-oriented R&D organisations. For example, the following is an extract from the purpose statement of the Defence Science and Technology Organisation (DSTO), Australia:

> "DSTO's business is to enhance the effectiveness of the Australian Defence Organisation (ADO) through the application of science and technology. We have a particular responsibility to support the ADO in those capabilities and technologies in which **excellence** would be most relevant to the direct defence of Australia and the policy of self-reliance.".

The National Aeronautics and Space Administration (NASA), USA, places an even stronger emphasis on "excellence" and "quality", as reflected in its mission statement:

> "We are committed to demonstrating and promoting **excellence** and continually improving processes, products, and services to better satisfy our customers' needs and requirements. We utilize **quality**-focused leadership and management, as well as scientific, engineering, and technical **excellence** to provide our customers with highly valued products and services in the most cost-effective, timely, and safe manner."

However, by its very nature R&D is not deterministic and is therefore difficult to quantify and assess in a numerical manner. The definition of "quality" itself is contextual and dependent on one's perspective. For example, this is dependent on the organisation and would differ between a large multi-national company, a small national one, and academia [6]. It is noted that only a few aspects of R&D can be quantified (*e.g.*, cost), and many aspects, such as outputs and outcomes, are hard to quantify. Therefore measuring the quality of research and development is fraught with difficulty. Nevertheless, it is very important to assess the research performance for a number of reasons:

(i) To provide meaningful information for external stakeholders, including the academic community;
(ii) To be accountable to the government and public who invest in the research;
(iii) To foster, maintain and improve the technical quality of the research programme; and
(iv) To provide a useful input to business planning processes by identifying and redirecting or terminating wayward research.

In the case of DSTO, whose main output is scientific and engineering advice, the credibility of DSTO's advice is strongly dependent on its quality or excellence of its research program.

To objectively assess the quality of research, it is essential that any indicators or measures should be transparent, objective, and collectable, which will be the emphasis of this report. In the present context, research quality is defined as the degree of excellence in the technical work itself (output) and exploitation or applications (outcome). In other words, the quality of any R&D needs to be measured and interpreted in terms of the value of research, both internal and external [3]. Internal criteria arise from within the science itself, and are basically criteria of efficiency or productivity—how well the research has been or will be conducted. Internal criteria are necessary criteria for the support of any R&D. External criteria are criteria of utility—that is, they measure the degree to which the given research is, in the broadest sense, useful outside the field itself. In the case of mission-oriented organisations, this means that the research should lead to ultimate applications. Research quality should also be judged against the motivations or objectives of the R&D undertaken, which may differ significantly between universities, industrial R&D organisations, and mission-oriented R&D organisations (such as DSTO). While the measures of internal quality may be common across these different types of research, indicators measuring the external

quality would be strongly dependent on the objectives of the research programme. Therefore a set of objective-dependent indicators are required for different type of research.

The present report will focus on the indicators applicable to mission-oriented research, while brief discussion of the various indicators employed for academic and industrial research will be presented for comparison purposes. Section 2 discusses the objectives of different types of research being carried out in universities, mission-oriented and industrial research organisations. A review and critical assessment of the quality indicators and the measuring process that are currently employed by various research funding bodies is presented in Section 3, together with the methodologies underpinning these current practices. A peer-reviewed-objective-dependent (PROD) approach is proposed in Section 4 for mission-oriented R&D organisations with a strong focus on meeting customer needs.

2. Classification of R&D and Research Objectives

Broadly speaking there are three main performers of R&D: (1) universities; (2) industrial R&D organisations; and (3) government laboratories. Examples of the last group of performers include laboratories funded by governments and the Department of Defence in many countries around the world, which will be denoted in this report as mission-oriented R&D organisations. A good classification framework of the broad spectrum of scientific and engineering research is provided by the OECD [7], which sets out the internationally agreed categories for surveys of R&D: basic research, applied research and experimental development. This classification was later refined to sub-divide the basic research into pure research and strategic research [8]. This refinement is particularly important as the strategic research covers the enabling research undertaken by most government laboratories and large science-based companies (in which it typically accounts for about 10 per cent of the R&D effort). The specific objectives of these different types of research are summarised in Table 1.

Table 1: Classification framework and objectives of R&D activities

Type of R&D		Objectives
Basic Research	Pure research	Advancement of knowledge, no efforts on application or transition of results.
	Strategic research	Broadening knowledge base and basis for solution of current or future practical problems.
Applied Research		Determining possible uses for findings of strategic research and solving already recognised problems.
Application and Development		Producing new or improved materials, products, devices, prototypes, and systems.

To a very large extent, the quality of research, *i.e.*, its impact and significance, is a reflection of the degree of innovation. Two very appealing models that have dominated the discussion of innovation over the past three decades are the "science-push" model and the "demand-pull" model, as depicted as follows [8]:

Curiosity-oriented research → Applied research → Experimental development → Innovation

Figure 1: Science-push model of innovation

Market demand → Applied research → Experimental development → Innovation

Figure 2: Demand-pull model of innovation

Considerable effort has been devoted in the past to ascertain which of the two competing models most accurately characterises the innovation process, trying to obtain systematic statistical evidence of most important factors contributing to innovation [8]. The results of these studies indicated that most innovations in practice fit neither of these simple models. In other words, the innovation process cannot generally be represented as a linear sequence of events with a single cause. Instead, it has been found that both "recognition of a technical opportunity" (science-push) and "recognition of a need" (demand-pull) have been identified as key factors of approximately equal importance in the most decisive events led to innovation.

The complicated interaction between science-push and demand-pull is prominent in the Defence Science and Technology Organisation (DSTO), which provides advice on the application of science and technology best suited to Australia's defence and security needs. DSTO conducts R&D in a wide variety of defence-relevant fields, focusing on areas which are unique to Australia's needs or otherwise central to national self-reliance. As emphasised in the Defence White Paper, science and technology play a central role in the success of Australia's defence. Australia has a relatively small population, and therefore Australia's defence policy gives priority to capabilities that rely on high technology rather than on large numbers of personnel.

Australia has four broad objectives for its defence science and technology advice. They are (i) to position Australia to exploit future developments in technology which show promise for defence applications; (ii) to ensure that Australia is an informed buyer of equipment; (iii) to develop new defence capabilities as required; and (iv) to support existing capabilities by increasing operational performance and reducing the costs of ownership, including life-extension programs.

During 1992-93, DSTO introduced several Program Improvement initiatives to provide extensive visibility of the Science and Technology program and to involve the customer group more extensively in program review and priority setting. The Program Improvement process has led directly to a substantial increase in customer satisfaction with DSTO's output and the balance of its products and services. However, considerable pressure within each research area, together with increasing customer awareness and requirements, has led to a sharpening of the competition for resources. A consequence of this process has been to reduce the quantity of long-term enabling R&D. It is nevertheless recognised that DSTO must manage and sustain a credible program of enabling R&D independently of immediate customer requirements but clearly mindful of future applications. The current structure of DSTO's research program can be approximately grouped into three categories [9]: enabling research, applied research and development, as depicted in Fig.3. Enabling R&D may have no immediate practical outcome but it should have the long-term potential for application and exploitation. Enabling R&D may provide a stream of novel and innovative ideas in areas of high technological risk and potentially high payoff.

By contrast to industrial organisations whose main outputs are products-for-profit, DSTO's main output is scientific and engineering advice. The credibility of DSTO's advice is therefore strongly dependent on its quality or excellence of its research program. The quality of its research also serves as a good indicator whether DSTO follows the best practice in R&D management. However, due to the different nature of DSTO's research as compared to that of university and industrial R&D organisations, conventional measures or indicators that have been widely used to evaluate the university research may be applicable only to the enabling research of DSTO. Other quality measures are required for the other two categories of research: applied research and development. This will be the focus of Section 4.

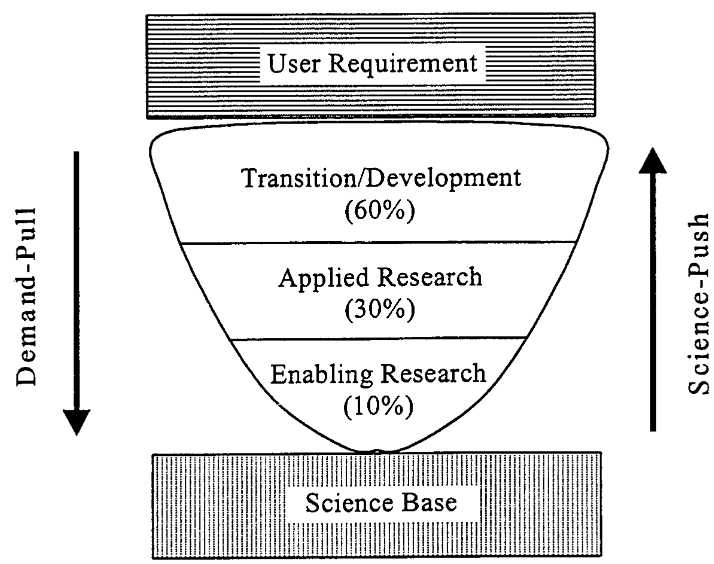

Figure 3: Push-pull model of DSTO's research and development.

To identify suitable indicators that may be applicable to mission-oriented R&D organisations, it is useful to review the quality indicators employed by the major research funding organisations.

3. Review of Quality Measures

The three main methods of measuring research quality are retrospective, qualitative and quantitative. For the three main R&D performers discussed in Section 2, universities, industrial organisations and mission-oriented government organisations, different sets of quality measure are required for each due to the differences in the objective of R&D undertaken by each organisation. The following review will focus on existing indicators that have been developed for academic research, industrial research, and mission-oriented research.

3.1 Academic research

The existing quality assessment as employed in decision making of research funding bodies to assist the allocation of research grants is centred around the peer review method, which represents evaluation by experts in the field. This is the method of choice in practice in many countries, including the USA, UK, and Australia.

For instance, the Higher Education Funding Councils in the UK conduct a Research Assessment Exercise (RAE), aimed to enable the higher education funding bodies to distribute public funds for research selectively on the basis of quality [10,11]. Institutions deemed to be conducting the **best** research receive a larger proportion of the available grant so that the infrastructure for the top level of research in the UK is protected and developed. Typically the quality assessment is carried out through the peer reviewing process, coupled with interviewing and site visits by a panel of experts. It takes place every four to five years. The RAE provides quality ratings for research across all disciplines. Panels use a standard scale to award a rating for each submission. Ratings range from 1 to 5, according to how much of the work is judged to reach national or international levels of excellence. The assessment involves a panel of internationally recognised experts to benchmark the quality on an international scale. The report provided by the panel amounts to a snapshot view of people well equipped to recognise excellence. Typically the evaluation framework encompasses Quality, People, Impact and Exploitability (QPIE), as summarised in Table 2.

It is important to note that the results of the research assessment have a much wider value than its immediate purpose. For example, it can be helpful in guiding funding decisions in industry and commerce, charities and other organisations that sponsor research. It also gives an indication of the relative quality and standing of UK academic

Publications

One important common indicator of research quality among university, industrial, and mission-oriented R&D organisations is refereed publications. There are a number of very important reasons for this strong emphasis on publications:

1. For enabling research, the technical issues being addressed have a generic relevance within the appropriate discipline, so that any significant progress or achievement should be publishable.
2. The more rigorous refereeing process involved in publishing journal papers serves to avoid duplication or "re-inventing the wheel" type of research.
3. Acceptance via peer-review process represents a highly objective peer-recognition of research quality.

Therefore the number of publications is not merely a measure of productivity, but also a very important indication of quality. It should be noted, however, that the calibre and peer regard for journals varies widely. The citation impact is therefore used as an indicator of relative quality. Furthermore, a citation analysis may be required to determine peers' assessment of the impact of the cited publication. Also, in a mission-focused context, journal publications should not be over-emphasised, as that may adversely modify behaviour by directing research away from the most relevant engineering problems with applications to industry towards projects which lead more readily to journal papers.

People

The skills and competence of the researchers are also a very important quality indicator. There is no doubt that the skills and competence of the people are essential to achieve international best practice in R&D. Therefore it is important to recruit, train and retain people with the best performance track record, and let them lead the research and development.

4.2 A Peer-Reviewed-Objective-Dependent (PROD) system

From the above analysis two things become clear. First of all, quality assessment needs to be based on peer review. In the case of research publications, peer view is by international experts or peers engaging in the same field of research. For application and development where the products are mostly in the form of scientific advice given to the customers, an assessment of quality requires direct inputs as feedback by the customers. Secondly, quality is value-system dependent and has to be assessed against the *objectives* of the research. This implies that a certain quality measure, like publication, may be more important for strategic research but less relevant for experimental development or commercial R&D. Therefore the weighting of quality measures need to be adjusted in accordance with the research objective. In other words, an appropriate quality assessment scheme for mission-oriented R&D

organisation has to be objective-dependent. Most mission-oriented R&D organisations conduct a mixture of R&D, including strategic research, applied research, and experimental development. For instance, DSTO conducts about 10% enabling research, 30% applied research and 60% application and development, as depicted in Fig.3.

The proposed new system, as illustrated in Table 6, aims to cater for the diverse spectrum of R&D undertaken by mission-oriented organisations. Firstly, three different sets of quality indicators are required for the three different levels of research. Secondly, the weightings of quality indicators would need to be adjusted to fit the characteristics of the field. For instance, in the case of strategic research aiming to broaden the science and technology base, the major quality measures should be similar to those widely employed by leading research grant funding bodies to measure the research quality of university research. In the case of development, it is more appropriate to place higher emphasis on outcome and customer satisfaction, and publications would be less critical although still important. It should be noted that although any one indicator does not guarantee quality, the lack of these indicators would certainly mean the lack of quality or excellence. Furthermore, a cardinal rule for the proper use of quantitative indicators is broken when any single indicator is relied upon.

To achieve a truly quantitative quality assessment, a bibliometrics approach has to be adopted: each indicator is ranked (e.g., using a rating between 1 and 10), the rating is multiplied by the weighting, and the results are added to arrive at the figure of merit. This will provide an objective method to benchmark one organisation's R&D performance against that of other similar institutions. In the case of DSTO, this would help to achieve efficiency and effectiveness to ensure that DSTO is providing "best value for service".

It should be cautioned here that it is important to ensure that the indicators do form an orthogonal set as much as possible, so there will be no multiple counting to skew the results. In addition, the rating of each quality indicator, such as research publication, is not simply a number counting. The marginal utility theory would suggest that that while it might be twice as valuable for researcher to publish two papers per year compared to one paper, it would probably not be twice as valuable if the researcher were to publish 100 papers per year as opposed to 50. Further research is required to identify the utility functions for these indicators.

Table 6: Research objectives, quality indicators and weighting

Research Objective	Quality indicator	Weightin g
Strategic research: Broaden science and technology base for solution of current and future practical problems.	1. Refereed publications.	40%
	2. Transition of research results to applied research or development.	40%
	3. Technical leadership: citations and track record of researchers.	10%
	4. Peer recognition: invited lecture and keynote talk at conferences.	10%
Applied research: Solve problems using established methodologies and principles, and	1. Conversion of science to technology.	50%
	2. Publications (external and internal).	30%
	3. Professionalism: track record of researchers	10%
	4. Peer review and benchmarking to ensure international best practice.	10%
Application and development: Provide ready-to-implement solutions to clients, and produce new or improved materials, products and systems.	1. Outcome: acceptance of advice by the clients.	50%
	2. Professionalism: customer satisfaction and best practice.	20%
	3. Publications (external and internal)	20%
	4. Spin-off, synergy, patents	10%

5. Conclusion

A critical review and comparison has been conducted on quality measures currently being employed to measure the performance of university research, industrial research, and mission-oriented research. A peer-reviewed-objective-dependent (PROD) evaluation system is proposed for mission-oriented research. This new quality assessment system advocates the use of different quality indicators that are consistent with the research objectives.

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19. ABSTRACT
This report explores suitable measures to assess the quality of mission-oriented research, with the view of identifying appropriate strategies to improve research performance. A peer-reviewed-objective-dependent (PROD) evaluation system is proposed to cater for the broad spectrum of research undertaken by mission-oriented research organisations, ranging from strategic research through to application and development. In the proposed PROD system, quality indicators and the pertinent weightings are adjusted to be consistent with the research objectives. It is possible to obtain a single number to quantify research quality using the bibliometrics method, in which the ratings are determined through peer reviewing. This quality assessment system could provide a useful tool for planning, priority setting, and quality assurance in research and development.

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